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RESEARCH PROGRAM IN FULLY DISTRIBUTED PROCESSING SYSTEMS.(U)
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THE GEORGIA INSTITUTE OF TECHNOLOGY

RESEARCH PROGRAM IN

FULLY DISTRIBUTED PROCESSING SYSTEMS

Quarterly Progress Report Number 7
1 March 1981 - 31 May 1981

June 1981

Supported by

Office of Naval Research (ONR)
Contract: N00014-79-C-0873
GIT Project: G36-643

U.S. Air Force Rome Air Development Center (RADC)
Contract: F30602-78-C-0120
GIT Project: G36-654

U.S. Army Research Office (ARO)
Contract: DAAG29-79-C-0155
GIT Project: G36-638

U.S. Army Institute for Research in
Management Information and Computer Science (AIRMICS)
Contract: DAAK70-79-D-0087
GIT Project: G36-647

National Science Foundation (NSF)
Contract: MCS-7924370
GIT Project: G36-652

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Atlanta, Georgia 30332

1. INTRODUCTION

This is the Seventh Quarterly Progress Report prepared covering the Georgia Tech Research Program in Fully Distributed Processing Systems (FDPS).

a. Program Description.

The Georgia Tech Research Program in Fully Distributed Processing Systems is a comprehensive investigation of data processing systems in which both the physical and logical components are extremely loosely coupled while operating with a high degree of control autonomy at the component level. The definition of the specific class of multiple computer systems being investigated, and the operational characteristics and features of those systems is motivated by the desire to advance the state-of-the-art for that class of systems that will deliver a high proportion of the benefits currently being claimed for distributed processing systems. The scope of individual topics being investigated under this program ranges from formal modeling and theoretical studies to empirical examinations of prototype systems and simulation models. Also included within the scope of the program are areas such as the utilization of FDPS's and their interaction with management operations and structure.

b. Program Support.

The principle support for the program is a Selected Research Opportunity contract from the Office of Naval Research; however, there are a number of other sources of funding which also support the program. A list of the currently active contracts and grants is given below.

Title: "Research on Fully Distributed Data Processing Systems"
Funding Agency: Office of Naval Research (ONR)
Contract Number: N00014-79-C-0873
GIT Project No.: G36-643/336
Principle Investigator: Philip H. Enslow, Jr.

Title: "Evaluation of Distributed Control Models"
Funding Agency: U.S. Air Force Rome Air Development Center (RADC)
Contract Number: F30602-78-C-0120
GIT Project No.: G36-654
Principle Investigator: Philip H. Enslow, Jr.

Title: "Theory of Systems of Asynchronous Parallel Processors"
Funding Agency: U.S. Army Research Office (ARO)
Contract Number: DAAG29-79-C-0155
GIT Project Number: G36-638/332
Principle Investigator: Nancy A. Lynch

Title: "Support of MILPERCEN Data Storage Concept"
Funding Agency: U.S. Army Institute for Research in Management Information and Computer Science (AIRMICS)
Contract Number: DAAK70-79-D-0087
GIT Project Number: G36-647
Principle Investigator: Alton P. Jensen

Title: "Complexity and Computability for Distributed Data Bases"
Funding Agency: National Science Foundation (NSF)
Contract Number: MCS-7924370
GIT Project Number: G36-652/340
Principle Investigator: Nancy A. Lynch

2. ORGANIZATION AND STAFFING

Faculty

Davida, George--Professor
DeMillo, Richard A.--Associate Professor
Enslow, Philip H. Jr.--Professor
Griffeth, Nancy--Assistant Professor
Jensen, Alton P.--Professor
LeBlanc, Richard--Assistant Professor
Livesey, Jon--Assistant Professor
Lynch, Nancy A.--Associate Professor
Miller, Raymond--Professor
Underwood, William -- Assistant Professor

Staff

McDonell, Sharon--Senior Secretary
Myers, Jeanette--Research Scientist
Pinion, Nancy--Part-time Secretary
Mongiovi, Roy--Research Technologist I

Students

There are approximately 30 students working on various projects in the FDPS Research Program. Of these, 12 are in the Ph.D. program, and 5 are preparing their M.S. Thesis on topics in FDPS.

3. CURRENT RESEARCH PROJECTS

The specific research projects have been organized into the major areas identified in the basic program proposal.

A. Theoretical and Formal Studies

A.2 Decomposition of Parallel Systems
A.3 Reliable Systems
A.4 Time Performance of Distributed Systems
A.5 Audit Algorithms
A.6 Ticket Systems
A.7 Synchronous Simulation

A.8 Distributed Resource Allocation
A.9 Theory of Distributed Databases
A.10 Arbiter Design
A.14 Using Complementary Distributed System Models
A.15 Probabilistic Algorithms in Distributed Systems
A.16 Stochastic Synchronization
A.17 Research Allocation in a Failure-Prone Environment

B. Physical Interconnection and Networking

B.2 Local Networking in Fully Distributed Processing Systems

C. Distributed Operating Systems

C.1 Decentralized and Distributed Control
C.2 Resource Allocation and Work Distribution in an FDPS
C.4 Local Operating System
C.5 Communications Support for Distributed Systems

D. Distributed Data Bases

D.1 Concurrency Control in Distributed Database Systems
D.2 Support of MILPERCEN Data Storage Concept
D.3 Implementation of the Audit Algorithm

E. Fault-Tolerance

F. Special Hardware to Support FDPS

G. Application of Distributed Processing

H. System Design Methodologies

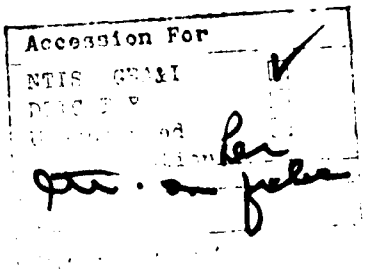
H.2 Coordinating Large Programming Projects

I. System Utilization

I.1 A Language for Distributed Programming
I.2 System Implementation Language Development
I.3 Experiments with a Distributed Compiler

J. Security

J.1 Process Structures
J.2 System Security



K. System Management

L. Evaluation and Comparison

L.1 Simulation of Distributed Algorithms (Griffeth, Lynch)

M. FDPS Testbed

M.1 Establishment of FDPS Testbed Facility
M.2 Remote Load Emulator
M.3 Fully Distributed Operating System Simulation Testbed

4. SUMMARY OF PROGRESS

A.2 Decomposition of Parallel Systems (Lynch, Fischer)

A paper, "On Decomposing Algorithms that use a Single Shared Variable", is in the process of being revised for journal publication.

A.3 Reliable Systems (Lynch, Fischer, Lamport)

Work has begun on writing up results proving lower bounds on the number of rounds of communication required to solve the Byzantine Generals problem (i.e. reaching agreement in the presence of faulty processors). The present focus is on determining appropriate models for the statement of this problem, especially for versions of the problem allowing encrypted messages. We would like to interpret the "number of rounds" lower bound as a lower bound on the time required for the solution.

A.4 Time Performance of Distributed Systems (Lynch, Fischer, Lazowska, Schönhage)

No significant progress to report.

A.5 Audit Algorithms (Griffeth, Fischer, Lynch)

The audit algorithm has been generalized still further. The final draft of a paper, "Global States of a Distributed System", has been submitted for presentation at the 1981 IEEE Conference on Distributed Systems and Software.

A.6 Ticket Systems (Fischer, Griffeth, Guibas, Lynch)

The paper, "Optimal Placement of Identical Resources in a Distributed System", was presented at the Second International Conference on Distributed Systems (Paris) on April 12, 1981.

Discussions were carried out for new designs of distributed ticket algorithms, as alternatives to those already studied. Several of these will be simulated using our general tree network simulator program, and compared with our basic algorithm.

Further tests were carried out on our basic ticket distribution algorithm: we tested the effect of allowing returns of tickets, and used a simple overestimate of step time to obtain upper bounds on response time, as expected interarrival time for requests was allowed to increase indefinitely. This upper bound was found to be a monotone increasing and bounded function of the expected interarrival time.

A graphics component for the simulator was completed and used in several demonstrations of the operation of our algorithm.

A.7 Synchronous Simulation (Lynch, Fischer, Arjomandi)

The paper, "A Difference in Efficiency Between Synchronous and Asynchronous Systems", was presented at the 1981 SIGACT Conference.

A.8 Distributed Resource Allocation (Lynch)

The paper, "Upper Bounds on Static Resource Allocation in a Distributed System", was accepted for invited publication in a special issue of the Journal of Computer and System Sciences based on the 1980 SIGACT Conference.

A.9 Theory of Distributed Databases (Lynch, Griffeth)

The paper, "Multilevel Atomicity - A New Correctness Criterion for Distributed Databases", was prepared for journal publication. It contains a definition for "multilevel atomicity", a new generalization of the usual notion of "serializability" used for correctness in distributed databases. This new condition seems to admit more efficient implementation than the usual definition, yet seems sufficiently general to allow expression of the conditions required for most real database applications.

Discussions were carried out to see how this generalization applies to the "Eden objects" used as the logical basis for the design of the local network at the University of Washington.

A.10 Arbiter Design (Lynch, Griffeth, Schönhage, Fischer)

No significant progress to report.

A.14 Using Complementary Distributed System Models (Lynch, Rounds, Miller)

No significant progress to report.

A.15 Probabilistic Algorithms in Distributed Systems (Lynch, Arjomandi, Fischer)

No significant progress to report.

A.16 Stochastic Synchronization (DeMillo, Miller, Lipton)

No significant progress to report.

A.17 Resource Allocation in a Failure-Prone Environment (Fischer, Lynch, Burns, Borodin)

Revision of a paper, "Resource Allocation with Immunity to Limited Process Failure", is being carried out for journal publication.

B.2 Local Networking in FDPSs (Enslow)

Since the last progress report, several new and some improved features have been incorporated into the local network. Many of the reliability problems have diminished due to our receipt of new software from Ungermann-Bass. We are continuing to work with Ungermann-Bass to isolate and solve the remaining performance problems.

Among the new features incorporated into the local network are a network-global name service, flow-control buffer thresholds, extended RS-232C control, and parallel data communications. Improved network throughput is the result of better internal buffer management and more efficient device drivers.

Hardware reliability has been greatly enhanced due to our receipt and incorporation of some minor hardware modifications.

The draft of a report detailing our experiences with NET/ONE and our future plans for local networking has been prepared.

C.1 Decentralized and Distributed Control (Enslow, LeBlanc, Saponas)

Evaluation of models of distributed control will be done through simulation. Work this quarter has been devoted to more thoroughly defining these models for the analysis stage and to the completion of the simulator.

C.2 Resource Allocation and Work Distribution in an FDPS (Enslow, Sharp)

A proposal to conduct a simulation experiment to evaluate the performance of several work distribution algorithms was finalized. This paper is entitled "Work Distribution in a Fully Distributed Processing System", and will be published shortly as a technical report.

C.4 Local Operating System (Livesey, LeBlanc, Spafford, Myers, Fukuoka, Pitts)

A program has been set up to explore methods of adapting the PR1MOS operating system to act as a LOS prototype. So far, areas covered have been the system kernel, device drivers, and high level system implementation languages. A secondary study has been carried out on file system structures for the LOS. An internal document, "The Local Operating System", has been completed and extensively discussed.

C.5 Communications Support for Distributed Systems (Enslow, Skowbo)

Progress this quarter has focused on the role of satellite communications in a FDPS. Multiple-access protocols have some interesting properties that seem ideally suited to the operation of such systems. These properites are being investigated, and methods for reducing or eliminating related problems, such as channel contention, are being studied. A long-range research plan has been established as a guide for further progress.

D.1 Concurrency Control in Distributed Database Systems (Griffeth, Livesey, Lynch)

The simulation framework for concurrency control algorithms in distributed database systems has been implemented. A technical report including a description of the simulation framework and instructions for its use is in preparation.

D.2 Support of MILPERCEN Data Storage Concept (Jensen, Doyle, Gehl, Bingham)

The final report is in preparation.

D.3 Implementation of the Audit Algorithm (Griffeth, Livesey, Lynch)

Three potential applications of the audit algorithm have been investigated for an initial implementation: the SERIES/1 file system, the ticket system (see Progress Summary for Project L.1), and the distributed database simulation of Project D.1.

The file system implementation has been postponed because the theory must be generalized still further to allow the number of nodes in the system to grow. The distributed database simulation will be the first implemented application of the audit algorithm.

H.2 Coordinating Large Programming Projects (Enslow, Underwood, Smith)

Research during this period focused on the development of a design model describing the process of large software development and an investigation of the relationship between problem solving and the software requirements and design specification process. Rittel's analysis of "wicked" problems in architectural design was applied to problems of the design of complex software systems.

I.1 A Language for Distributed Programming (LeBlanc, Maccabe)

Design and implementation work continued this quarter. A technical report was published and a presentation on our work was given during a visit to the Siemens Research Laboratories in Munich.

I.2 System Implementation Language Development (LeBlanc, Akin)

No progress during this quarter. Work by Akin will resume during the next quarter.

I.3 Experiments with a Distributed Compiler (LeBlanc, Moore)

A M.S. Thesis by Moore has been completed. Work on refining and extending these experiments may begin during the next quarter.

J.1 Process Structures (DeMillo, Lipton, Miller)

We have isolated a class of cryptographic problems and are working on a model of cryptographic protocols. The intent of this model is to allow precise formulation of problems of the following type:

> There is no protocol built on a cryptosystem of type x that satisfies the property D.

The protocols that are allowed can be both deterministic and probabilistic. To date, a number of protocol problems have been translated into the model.

J.2 System Security (Livesey, Davida, DeMillo)

A paper by Livesey and Davida, "An Architecture to Support Secure Operating Systems", was presented at the Second Symposium on Security and Privacy.

L.1 Simulation of Distributed Algorithms (Griffeth, Lynch)

The graphics for the ticket system simulation have been completed. Also, the simulation experiments have proved to be consistent with the "monotonicity" hypothesis for the ticket system algorithm. The hypothesis states that the expected response time increases monotonically with the interarrival time.

Work is in progress on the development of new algorithms for the ticket system. It is expected that any reasonable algorithm will obey the monotonicity property. The cost of two other properties, fairness and the absence of starvation, will also be studied.

M.1 Establishment of FDPS Testbed Facility (Myers, Mongiovi, Pitts, Fox)

A preliminary design for distributed software tools (DSWT) is complete. DSWT will consist of one or more software tools subsystems (SWT) which communicate to locate and utilize resources and make decisions. SWT is a subsystem developed at Georgia Tech which operates under the PR1MOS operating system on PR1ME P350 and larger computers. The subsystem is a complete interface between the user and the PR1ME computer system. It offers a powerful command language similar to the one offered in UNIX, a programming environment, and a hierarchical file system. Many of the concepts behind software tools stem from those found in MULTICS and UNIX and especially from the book Software Tools by Brian W. Kernighan and P.J. Plauger. The general objective of DSWT is to expand upon the capabilities provided by SWT (implying a minimum of implementation effort), to explore some fully distributed processing concepts. DSWT will provide the following:

1. A distributed file system and an associated naming server.

2. Work distribution. Deciding where a process is to be run can depend on the location and size of the data file the process accesses, the current load on each of the individual systems of the network, the resources required by the process, etc.

3. Network utilities like 'mail', 'news', 'to', 'status', and file transfer that operate on a network-wide basis. Network utilities are actually 'applications' and DSWT will provide the framework for applications programs to be written as a set of concurrently executing processes which communicate using the network communication routines implemented during the previous quarter. This will include the ability to 'invoke' remote proceses, establish connections for future communication, and provide error handling, network port servers, remote file access, etc.

M.2 Remote Load Emulator (Myers, Enslow, Forsyth)

The implementation of the Remote Load Emulator is complete. Some preliminary tests have been made, and the emulator has successfully run 20 simultaneous terminal sessions. The M.S. Thesis describing the emulator is being written.

M.3 FDOS Simulation Testbed (LeBlanc, Saponas, Myers)

Work on the simulator continues in support of projects C.1 and C.2.

5. TRAVEL RELATED TO THE FDPS PROGRAM

Date of Trip: 6-11 April, 1981
Individual(s) Traveling: Richard LeBlanc
Itinerary: Paris, France
Purpose: Attend Second International Conference on Distributed Computing Systems.

Date of Trip: 6-11 April, 1981
Individual(s) Traveling: Nancy Griffeth
Itinerary: Paris, France
Purpose: Present paper, "Optimal Placement of Identical Resources in a Distributed System", at the Second International Conference on Distributed Systems.

Date of Trip: 9-13 April, 1981
Individual(s) Traveling: Nancy Lynch
Itinerary: Milwaukee, Wisconsin
Purpose: Attend 1981 SIGACT Conference (paper presented by coauthor, Arjomandi).

Date of Trip: 2-15 April, 1981
Individual(s) Traveling: Richard LeBlanc
Itinerary: Munich, West Germany
Contact: Anton Sauer
Purpose: Visit Siemens Research Laboratories.

Date of Trip: 20 April, 1981
Individual(s) Traveling: Jon Livesey
Itinerary: Oakland, California
Purpose: Present paper, "An Architecture to Support Secure Operating Systems", at the Second Symposium on Security and Privacy

Date of Trip: 30 April - 3 May, 1981
Individual(s) Traveling: Philip Enslow
Itinerary: Las Vegas, Nevada
Purpose: Present talk on the status of distributed processing at Interface '81.

Date of Trip: 18-20 May, 1981
Individual(s) Traveling: Philip Enslow
Itinerary: San Diego, California
Purpose: Present talk on Distributed Computing Systems at Naval Ocean Systems Center.

Date of Trip: 21-22 May, 1981
Individual(s) Traveling: Philip Enslow
Itinerary: Wrightville Beach, North Carolina
Purpose: Participate in Army Workshop on Research Directions for Multi-Micro Computers.

Date of Trip: 27 May, 1981
Individual(s) Traveling: Philip Enslow and Jon Livesey
Itinerary: Hampton, Virginia
Purpose: Explore applications of FDPS in avionics at NASA, Langley AFB.

6. VISITORS

Dates of Visit: 15-17 April, 1981
Visitor: Andrew C. Yao, Stanford University
Contact: Richard DeMillo
Purpose: Research collaboration and presentation entitled, "The Security Problem for Public-Key Protocols".

Dates of Visit: 27 April, 1981
Visitor: Bob Grafton, Dave Mizell, ONR.
Contact: Albert Badre, Richard DeMillo, Philip Enslow, Nancy Griffeth, Richard LeBlanc, Jon Livesey, Nancy Lynch, Raymond Miller
Purpose: Discuss FDPS Research Program.

7. PUBLICATIONS

Author(s): M. Fischer, N. Griffeth, L. Guibas, & N. Lynch
Title: Optimal Placement of Identical Resources in a Distributed System
Type: Conference Paper
Status: Presented and published in Proceedings of the Second International Conference on Distributed Systems (Paris, France).
Publ. Date: April, 1981

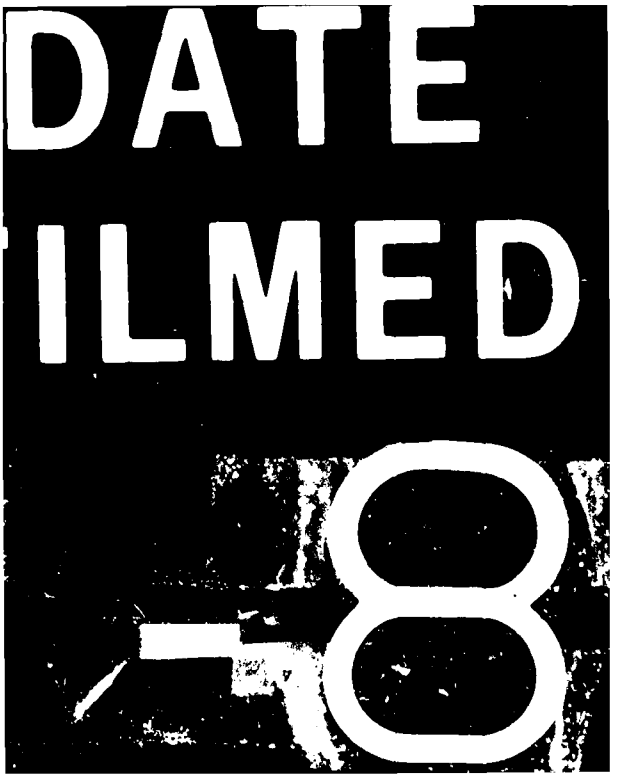
Author(s): J. Livesey & G.I. Davida
Title: An Architecture to Support Secure Operating Systems
Type: Conference Paper
Status: Presented and published in Proceedings of the Second Symposium on Security and Privacy (Oakland, California).
Publ. Date: April, 1981

Author(s): E. Arjomandi, M. Fischer, & N. Lynch
Title: A Difference in Efficiency Between Synchronous and Asynchronous Systems
Type: Conference Paper
Status: Presented and published in Proceedings of the 1981 SIGACT Conference.
Publ. Date: May, 1981

Author(s): R.J. LeBlanc and A.B. Maccabe
Title: PRONET: Language Features for Distributed Programming
Type: Technical Report
Status: Published
GIT Number: GIT-ICS-81/03
Publ. Date: May, 1981

Author(s): Gregory L. Moore
Title: A Distributed Compiler
Type: M.S. Thesis
Status: Presented
Publ. Date: May, 1981

Author(s): N. Lynch
Title: Upper Bounds on Static Resource Allocation in a Distributed System
Type: Journal Paper
Status: Accepted by the Journal of Computer and System Sciences.
Publ. Date: To be determined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